

Connecting Climate and Marine Ecosystems

Presented by

Charles Stock

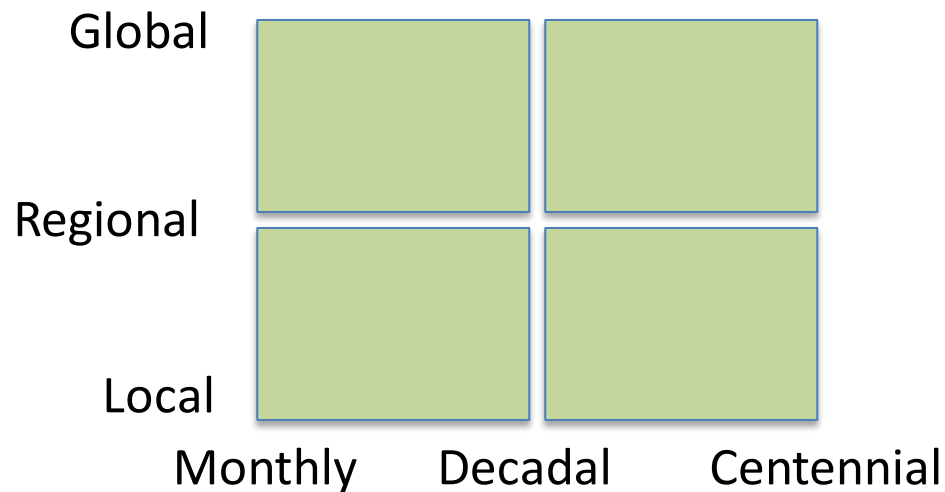
Geophysical Fluid Dynamics Laboratory Review

May 20 – May 22, 2014



Objectives

Robust, quantitative predictions and projections of climate-ecosystem interactions across spatial and temporal scales



In support of NOAA
NGSP Goals:

- Climate Adaptation and Mitigation
- Healthy Oceans
- Resilient Coastal communities and economies

- Led comprehensive synthesis on the use of IPCC-class climate models to assess climate impacts on living marine resources (Stock et al., Prog. in Oceanogr., 2011; 120, 1-28)
- Led or co-authored 30 published studies to assess climate impacts on living marine ecosystems
- Advanced marine ecosystems models within ESMs, yielding new insights into marine resource sensitivity to climate change
- Developing innovative marine ecosystem applications for new GFDL climate predictions and projections

Interdisciplinary collaborative efforts essential for meeting our objective

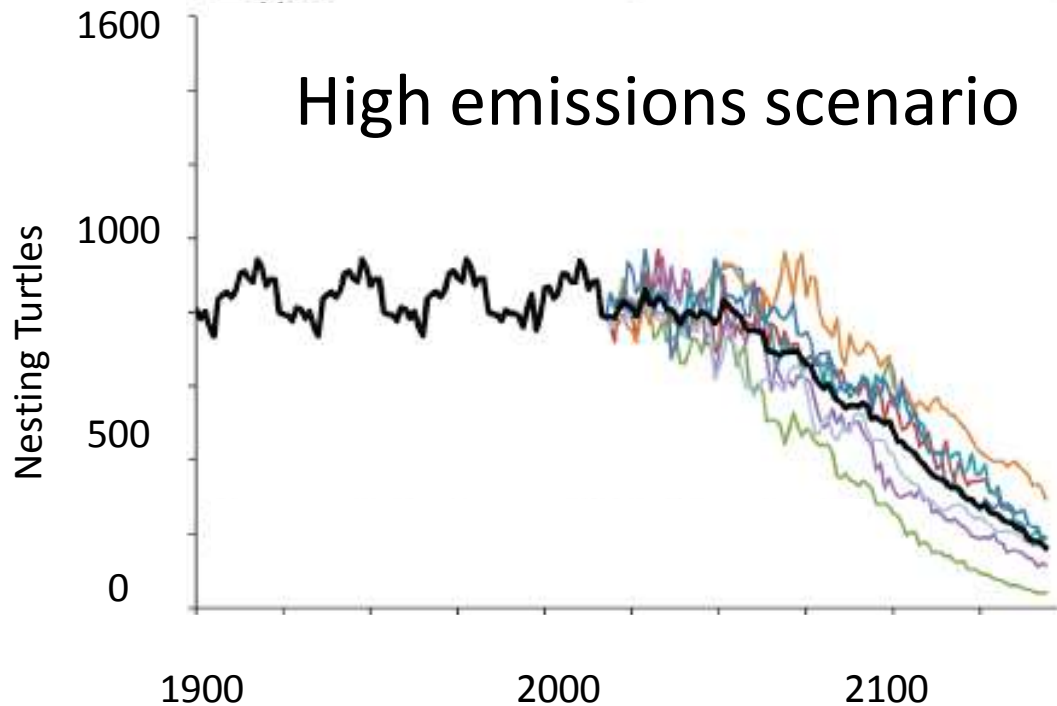
Negative impacts on endangered leatherback turtles

- Hatch and emergence success depend on temperature and precipitation
- Sex ratio depends on precipitation levels
- Returns to land for nesting depend on ocean productivity (cold, La-Nina conditions indicate more productive ecosystem)



Saba, V. S., C. A. Stock, et al., 2012: Projected response of an endangered marine turtle population to climate change. *Nature Climate Change*. 2, 814-820.

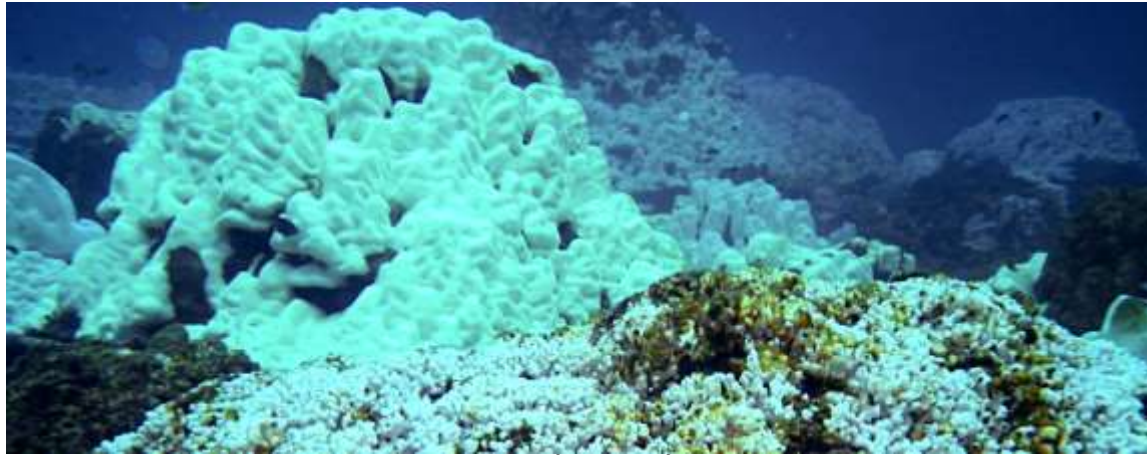
Negative impacts on endangered leatherback turtles



- Project declining numbers due to lower hatching/emergence with increasing temperature
- Nesting further north unlikely due to extremely dry conditions in sub-tropics
- Potential to maintain population through irrigation and shading if projected impacts begin to manifest.

Saba, V. S., C. A. Stock, et al., 2012: Projected response of an endangered marine turtle population to climate change. *Nature Climate Change*. 2, 814-820.

Adaptation & climate change impacts on coral reefs

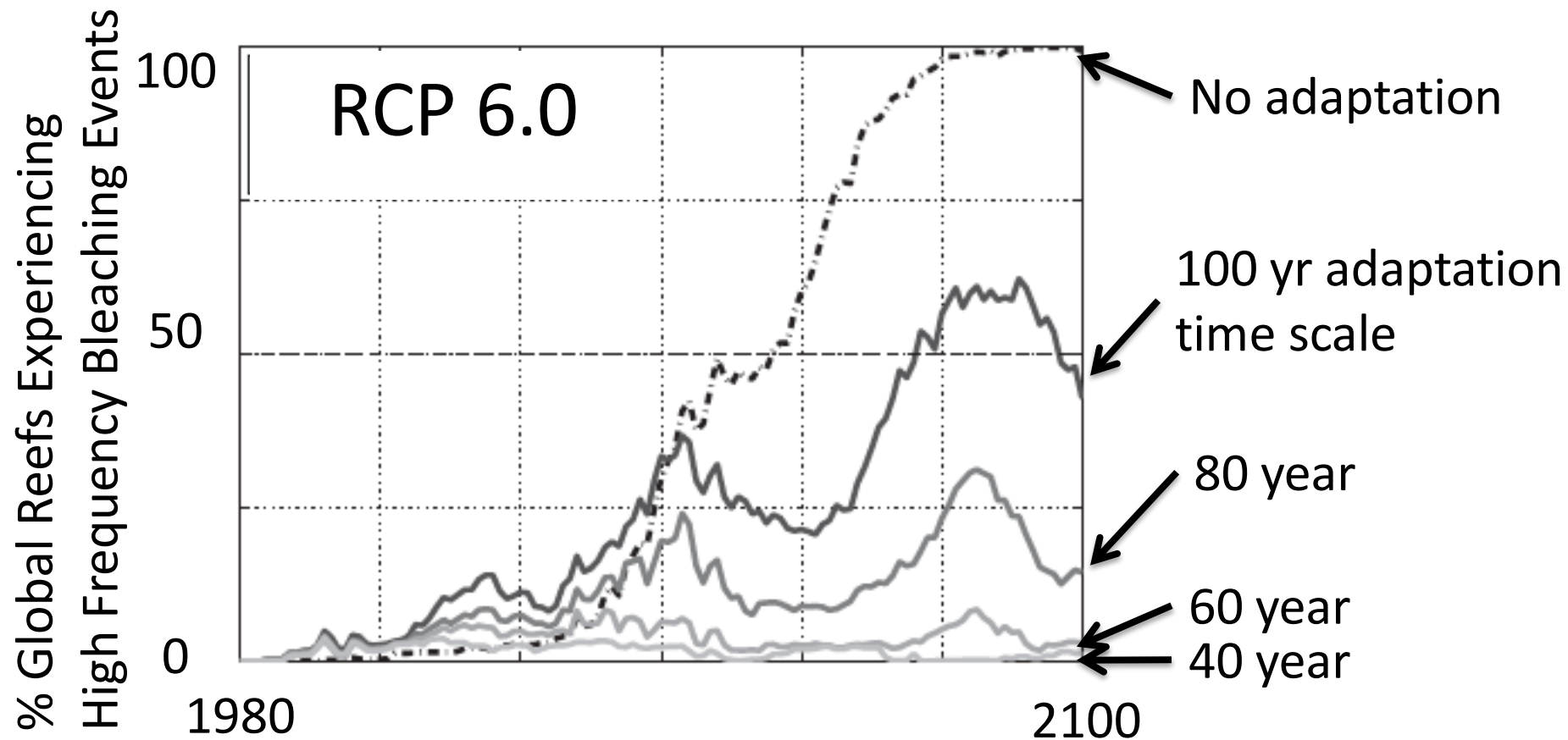


Oceanservice.noaa.gov/facts/coral_bleach.html

- Stressed corals, including those exposed to warming, may expel symbiotic algae that provide much of coral's nutrition.
- > 1 degree heating month above maximum monthly mean temp in a span of 3 months = likely bleaching

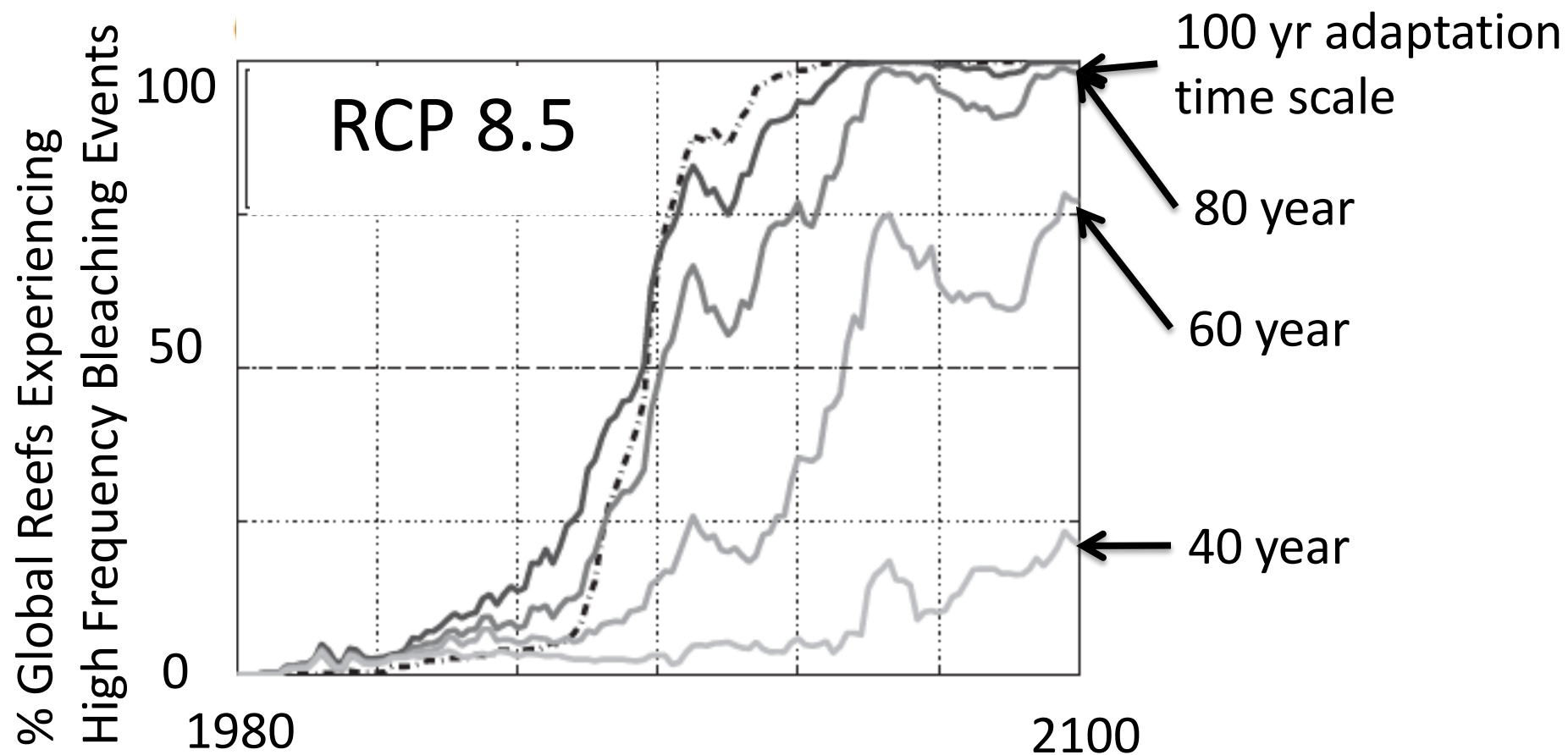
Logan, C.A., J. P. Dunne, et al., 2014: Incorporating adaptive responses into future projections of coral bleaching. *Global Change Biology*. 20, 125-139.

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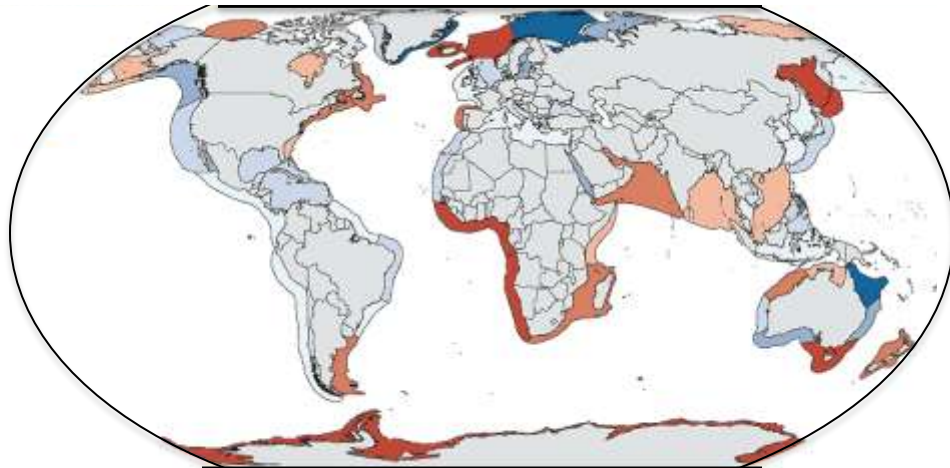
Progress and Challenges

- Present assessments: magnitude, direction, and first-order drivers of climate-change impacts
- Priority developments:
 - Strengthen mechanistic and quantitative connections between climate drivers and ecosystem responses
 - Provide predictions and projections on time-scales ranging from seasons to centuries.
 - Improve resolution of local/regional impacts
 - Consider responses to multiple stressors

Stock et al., *On the use of IPCC-class models to assess the impact of climate on Living Marine Resources*. Progress in Oceanography 120, 1-28.

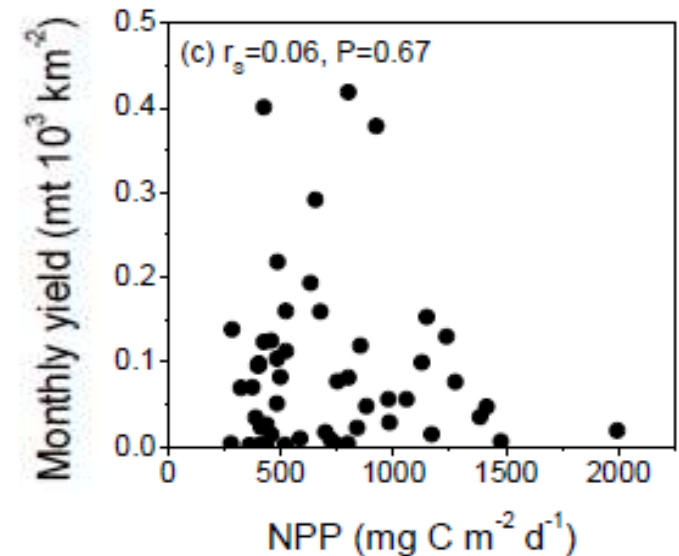
Connecting climate and global fisheries

Primary production alone is not a good indicator of fisheries yields



Large Marine Ecosystems

Ken Sherman (NOAA/NMFS)



Friedland, K. D., C. A. Stock, et al., 2012: *Pathways between Primary Production and Fisheries Yields of Large Marine Ecosystems*. PLoS ONE

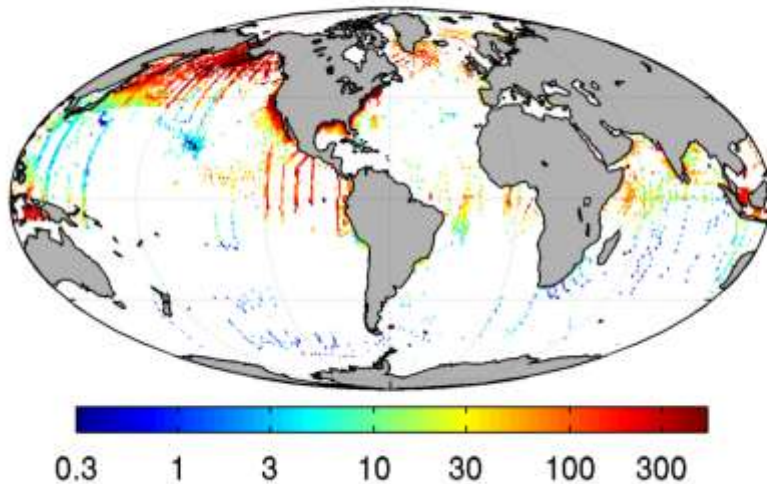
COBALT Marine Ecosystem Model

- Capture interactions between climate and ocean biogeochemistry with a more resolved, mechanistic representation of the plankton ecosystem dynamics.
- Capture the impact of climate on the flow of carbon and energy through the planktonic food web to fisheries and other living marine resources
- A robust, quantitatively supported baseline for continued model development

Stock, C.A., J. P. Dunne, and J.G. John, 2014: *Global-scale Carbon and Energy Flows through the Marine Planktonic Foodweb*. Progress in Oceanography 120, 1-28.

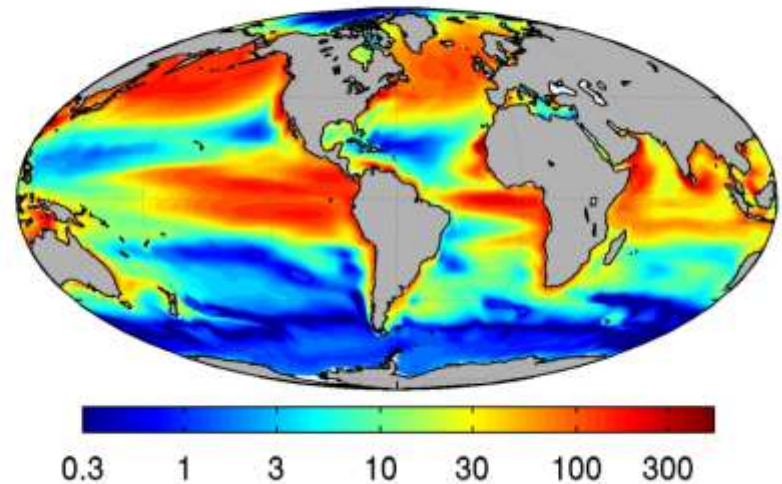
Quantitative C fluxes throughout plankton foodweb

C: $\log_{10}(\text{Est. Mesozoo Prod, mg C m}^{-2} \text{ d}^{-1})$



Obs-based mesozooplankton production
(NOAA Copepod database, O'Brien, 2005;
Hirst and Bunker, 2003; SeaWiFS)

D: $\log_{10}(\text{Mod. Mesozoo Prod, mg C m}^{-2} \text{ d}^{-1})$

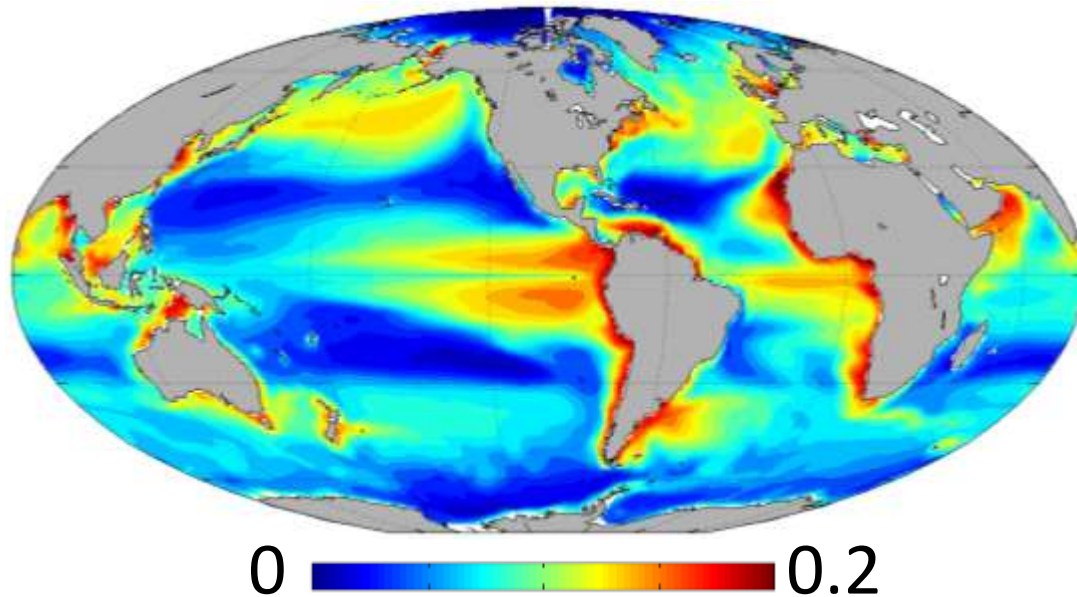


Mesozooplankton production in GFDL's
COBALT ecosystem model

Stock, C.A., J. P. Dunne, and J.G. John, 2014: *Global-scale Carbon and Energy Flows through the Marine Planktonic Foodweb*. Progress in Oceanography 120, 1-28.

Spatial differences in foodweb transfer efficiency

Ratio of Mesozooplankton Production
to Primary Production

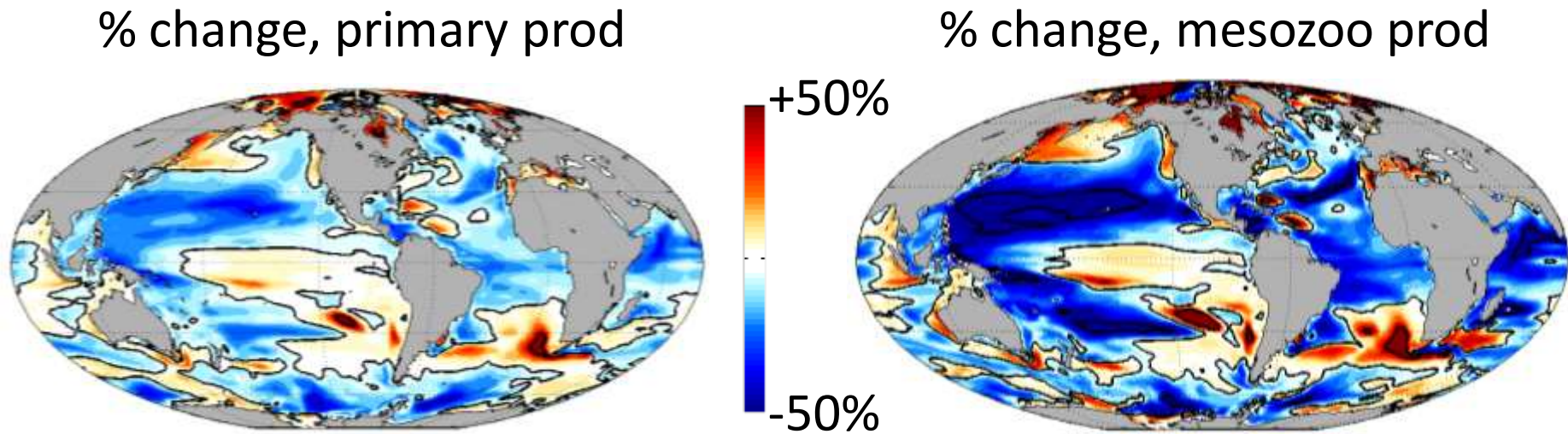


Attributed to spatial
variations in 3 factors:

- Number of trophic steps between phytoplankton and mesozooplankton
- Efficiency of trophic links
- Strength of coupling between consumers and phytoplankton in surface ocean

Stock, et al., 2014: Progress in Oceanography 120, 1-28.

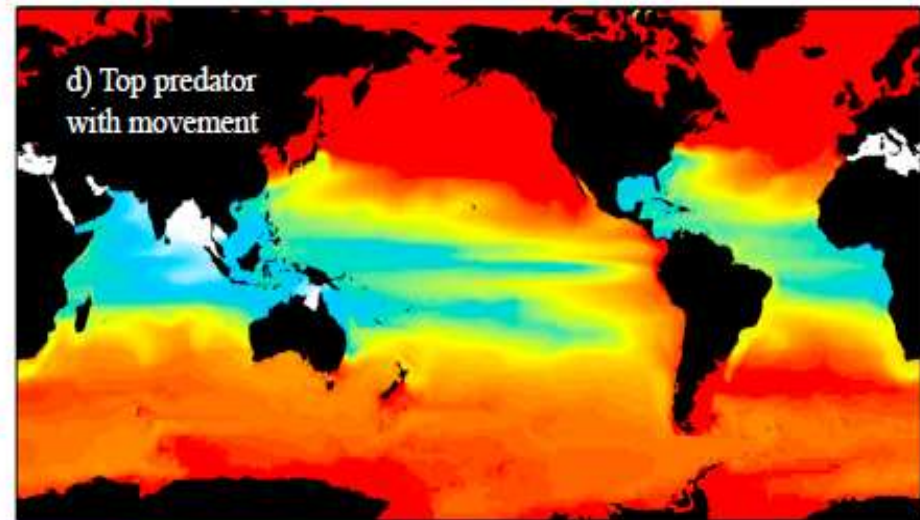
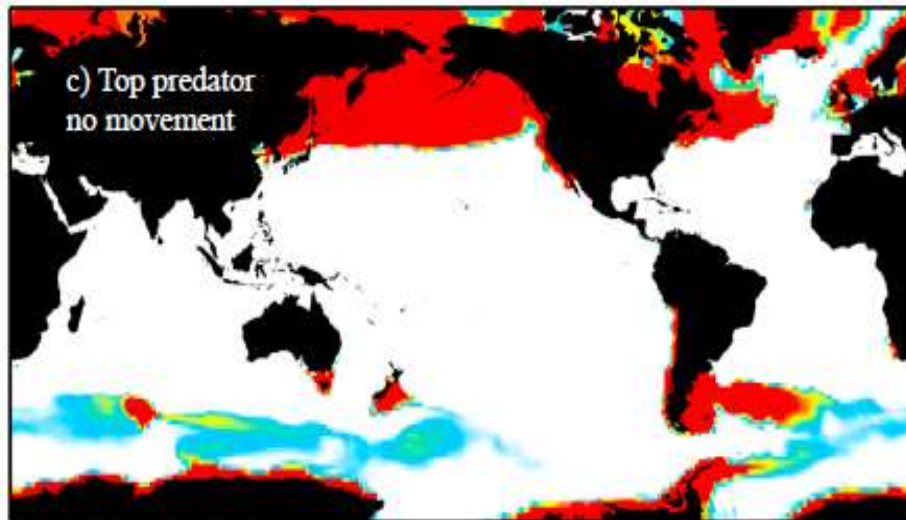
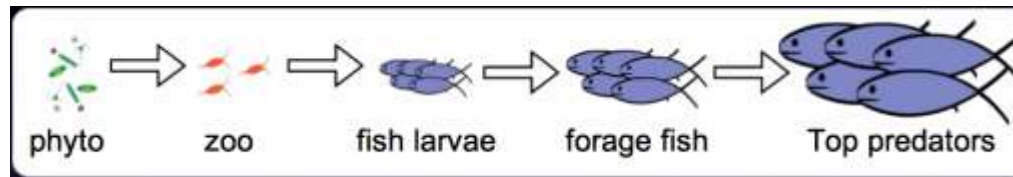
Amplification of ocean productivity changes



- Projected percent changes in mesozooplankton productivity are 2X primary productivity changes
- Large regional changes
- Quantitative attribution to the same planktonic food web characteristics that drive spatial gradients

Stock, C.A., J. P. Dunne, and J.G. John, submitted: *Understanding trophic amplification of ocean productivity trends in a changing climate.*

Simulating global fish dynamics

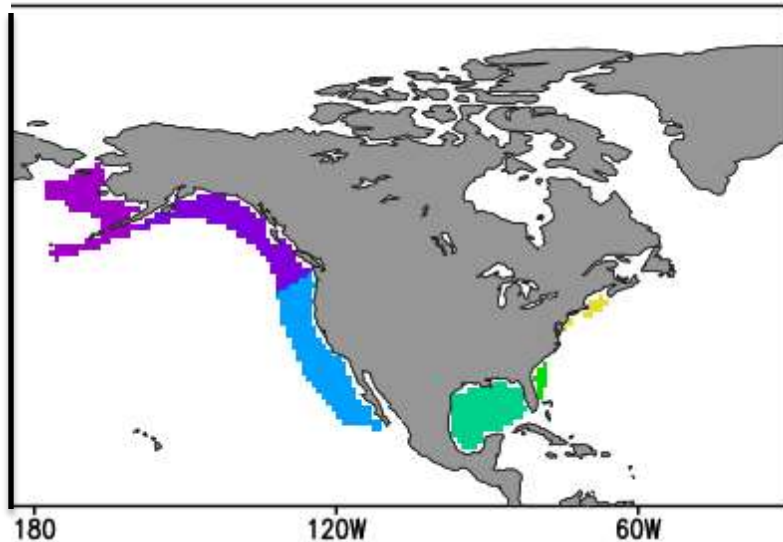


Watson, J., C. A. Stock, J. Sarmiento, in revision, *The role of movement in determining the global distribution of marine biomass*. Progress in Oceanography

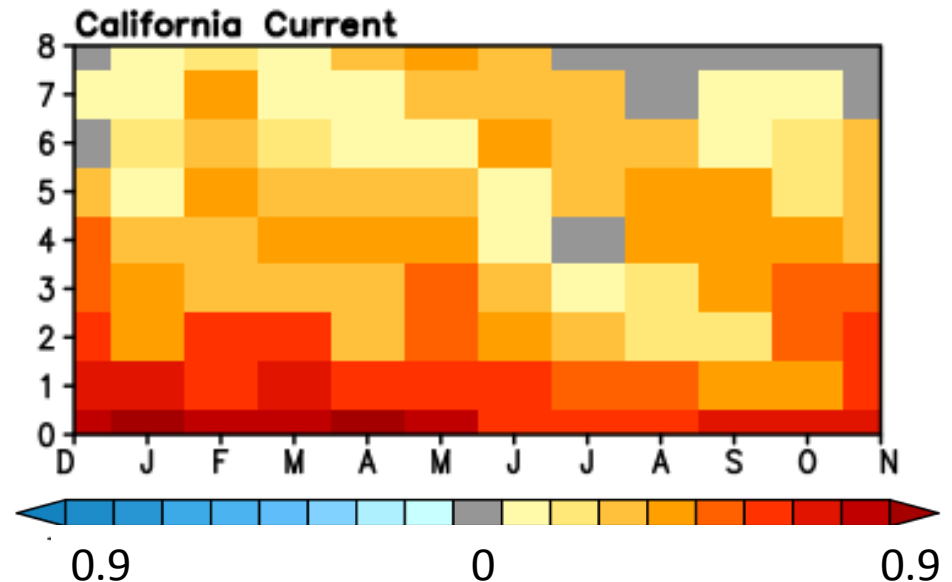


Seasonal/decadal predictions for marine resources

How predictable are shelf scale hydrographic anomalies?



GFDL CM2.1 SST anomaly
Correlation for Cal. Current

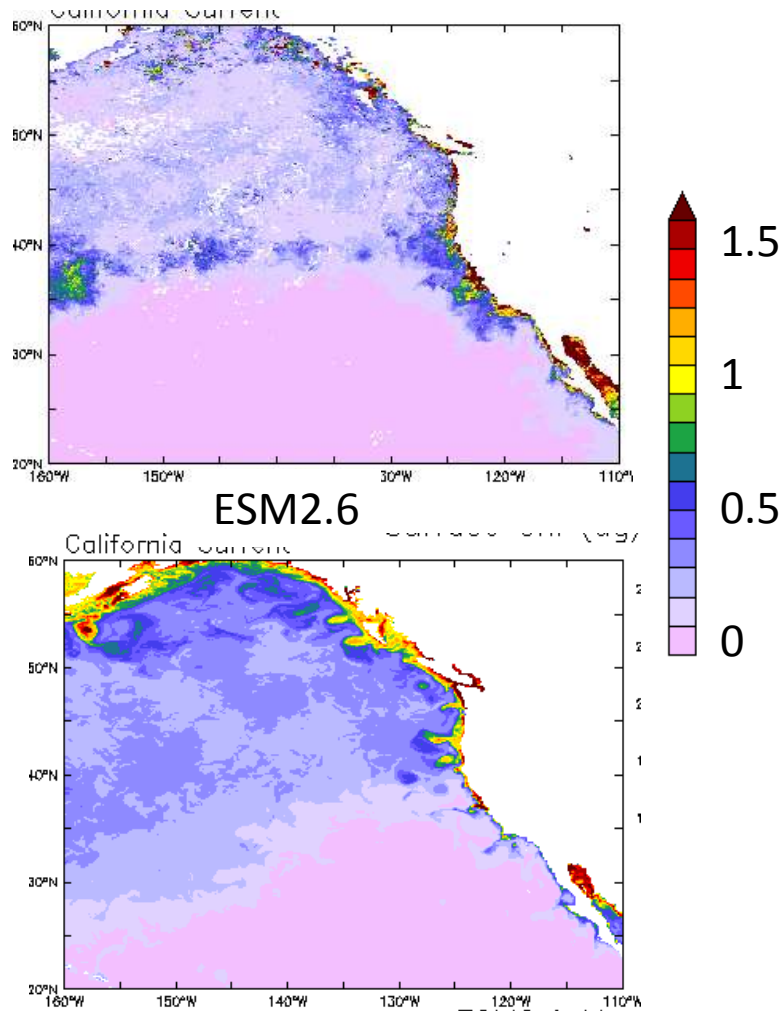


How many sardines
should we catch next
year?

SEED Grant, OAR/NMFS S&T – GFDL, ESRL, NCEP, PMEL, NMFS

High-resolution ESMs

Satellite Chlorophyll (mg Chl m^{-3})

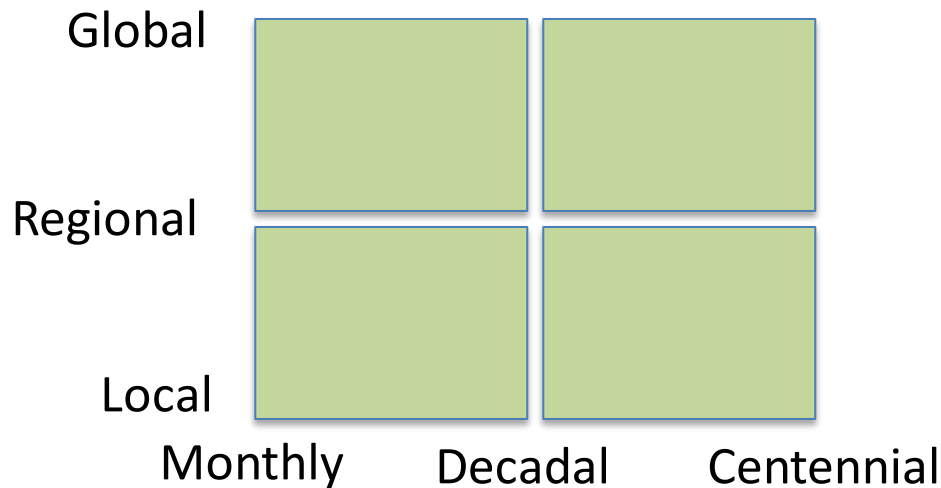


- What controls marine resource yields across global shelf ecosystems?
- What is the role of shelves in global biogeochemical cycles?
- Where are abrupt change in shelf ecosystems likely? Which stressors drive these changes?
- How can we improve integration of global and distributed regional ecosystem modeling capacity?



Summary

Robust, quantitative predictions of climate-ecosystem interactions across scales through integration of ecosystem dynamics across GFDL model configurations



Building confidence in ecosystem predictions by:

- Increasingly rigorous and holistic model-data comparisons
- Progressive incorporation of improved ecology and physiology based on principles expected to hold in a changing climate